



INTEGRATION OF SOLAR AND WIND ENERGY: A REVIEW OF CHALLENGES AND BENEFITS

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Abstract: Renewable energy (RE) is rapidly evolving into one of the primary independent energy sources for human living and will play a significant role in power generation in the future. Nowadays, some people prefer to employ RE sources like solar or wind energy in their homes or on their property. The evaluation of the difficulties and advantages of combining solar and wind energy is presented in this paper. Some integration-related problems, such as the power quality standards that must be satisfied to set up this connection properly, will also be discussed in the paper. Forecasting of RE, which includes the availability of electricity at any given time, the rate of change, and the location of the RE source, is another challenge that may impede the proper integration of RE with the grid. The study also briefly illustrates a mechanism that can be applied in households to make this connection. The benefits of integration for the power company and owner of green energy are discussed last, along with how this integration may impact the environment. In this study, examples of RE will include solar energy and wind energy.

Keywords: *Integration, renewable energy (RE), solar energy, wind energy, green energy.*

1.1 INTRODUCTION

The electricity system is changing in many parts of the world due to powerful forces, including climate change, & a growing public opposition to nuclear power. In previous hydrothermal systems, more and more RE sources are being used, particularly wind and solar. These sources provide erratic and unpredictable amounts of electricity, making it difficult to integrate them into established power grids. Uncertainty is a problem because it could lead to inadequate system preparedness to balance variations from

“variable generation” (VG). For instance, in response to the unexpected wind picking up or calming down, the schedules of thermal power plants must be immediately modified. However, even under ideal conditions for forecasting, the unpredictability of wind & solar power output places a strain on the operation of the system in 2 different ways: it may cause balancing resources to cycle more frequently, and it may cause ramps with extreme steepness/duration. Both of these types of ramps put the system under stress. It is necessary for the power system to be adaptable in order to handle the problems that are presented (Huber et al., 2014).

1.2 WIND ENERGY INTEGRATION

By realising the objective of a low-carbon civilization, environmental preservation is essential to protecting the world from environmental calamities. The energy mix can be optimised by adding wind energy to the system & reducing reliance on sources of traditional energy. In order to integrate wind energy output, significant changes must be made to the current grid system, which was largely designed for conventional energy sources. Owing to the unpredictable and fluctuating nature of wind energy, grid stations must deal with the challenges of battery storage systems & high transmission. Figure 1 depicts a sophisticated power system architecture utilising wind energy. WTs utilise several generators described in Section 2 to convert kinetic energy of the wind into electrical energy. Since battery may store energy for use during peak hours, wind energy’s intermittent nature is reduced. DC power is then converted from

AC power. A dc source can be utilised to power "High Voltage DC" (HVDC) energy transmission systems. The grid facility is then outfitted with a DC-to-AC converter to convert HVDC voltage to AC voltage at a predetermined frequency. In grid station, "voltage source converters" (VSC) and filters are installed to reduce harmonic distortion in voltage waveform during power conversion (Asghar et al., 2022).

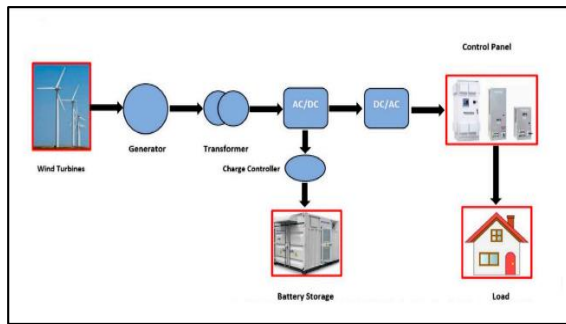


Figure 1: Wind energy integration

1.3 SOLAR ENERGY INTEGRATION

The use of solar energy to power spacecraft in orbit was one of the earliest applications of photovoltaic technology. Photovoltaic modules are utilised for utility-interactive power generation the vast majority of the time. Solar energy systems that are connected to the grid are often divided into three different categories: residential, commercial, and utility scales. The residential scale is the least powerful type of installation, which includes all systems with a power output of 10 kW or less and is typically located on private property.

Solar grid integration refers to the method through which solar photovoltaic (PV) energy can be included in the national utility grid. The rising global demand for the use of alternative clean fuels and the rising global installed capacity of solar power is driving the broad adoption of solar grid integration. Grid-connected solar power generation primarily falls into two categories: distributed generation and utility-scale generation.

Due to economies of scale, centralised utility-scale power is economically superior to scattered generation and considerably simpler to manage. Distributed solar PV integration offers special advantages such as decreased line losses, greater grid resilience, avoided generation costs, and decreased operation costs (Min, 2022).

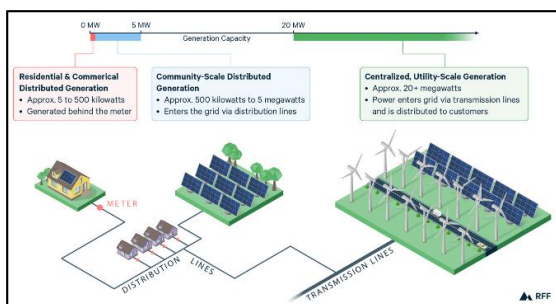


Figure 2: Solar energy integration

1.4 ADVANTAGE OF WIND AND SOLAR – HYBRID SYSTEM

The primary benefit of this method is that it provides reliable electricity to remote areas where grid power is not yet available. A battery bank can be used to store energy produced by RE sources such as wind turbines or solar panels. When two or more

RE sources are used, as is commonly the case with solar & wind power, the system is called a hybrid RE system. By integrating solar and wind power production, hybrid systems boost system dependability.

Moreover, battery storage size can be slightly reduced because there is less reliance on one form of power supply. When the sun's resources are at their greatest (summer, eventually), wind speeds are frequently low. On the other side, when there is less sunlight, the wind is frequently stronger. There are various and opposing patterns regarding wind & solar resources even within the same day, in many places around the world or during some seasons of the year. And because of those various patterns, hybrid systems may be the best choice.

"Wind-solar electric hybrid systems" have a higher initial cost than single bigger systems. This is due to the fact that larger wind and solar PV systems have a lower per-watt cost than their smaller counterparts. When there is a significant increase in productivity and performance, however, the hybrid strategy is the way to go. This happens when the sun's and wind's cycles and intensities are at odds with one another at various times of the day or year (Aazam et al., 2015).

1.5 CHALLENGES AND BENEFITS OF INTEGRATING THE RE

The paper will explore some of the difficulties and advantages of integrating renewable energy in this sector.

1.5.1 The Challenges

The majority of renewable energy sources rely on unregulated resources. In other words, the energy generated by RE comes from sources of nature, such as wind, sunlight, & ocean waves. This type of information enables us to understand how sporadic and irregular RE power generation is.

As a consequence of this, integrating power generated by renewable energy sources into the conventional electrical grid is an arduous task. There are various challenges that arise as a result of this incorporation, and figure 3 illustrates the primary concerns that will be addressed in the following manner: cost, location of RE resources, availability of power, power quality, & rate of change in power are some of the factors that are taken into consideration.

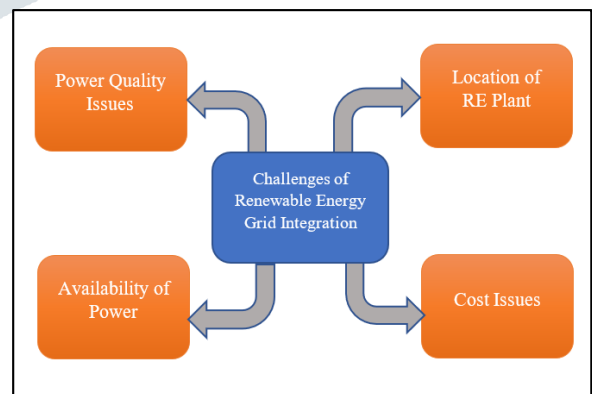


Figure 3: Challenges of Renewable Energy Grid Integration

1.5.1.1 Power Quality Issues

Power quality (PQ) is crucial to the reliability & cost-effectiveness of power grids and power systems. On the other side, low PQ can lead to catastrophes like power outages, inflated prices, and broken machinery. Several research and Schneider

Electric estimate that the United States loses 15 billion USD yearly due to power quality issues in industrial processes. Transmission line transits, voltage fluctuations, poor power factors, and harmonics in voltage and current are all instances of PQ problems. Since RE technologies' power output fluctuates, PQ problems affect both on-grid and off-grid systems. As this is the case, when the integration is planned, these worries are going to have a negative impact on the grid. For instance, if the power factor of the system drops to an extremely low level, the apparatus will be damaged (Fridley, 2010). In addition, the voltage and frequency of solar energy are not constant because of the amount of irradiance; as a result, this causes voltage and frequency deviation; these 2 deviations are key hurdles in the process of integrating RE into the grid (Alsaif, 2017).

1.5.1.2 Availability of Power

The dependence of electricity generation on uncontrollable natural resources is one of the main issues with RE-Grid integration. In PV energy, as depicted in figure 4, electricity production is continuous during daylight hours and ceases at night. Similar to solar energy, wind energy also depends on the existence of wind; so, if the wind speed is very low or zero, the turbine will not revolve, preventing any power from reaching the grid (Alsaif, 2017). The inconsistent nature of energy production in RE technologies makes their integration more challenging and has detrimental effects on the system's performance, such as harmonics in the converters, unless solutions have been found, such as storage systems like batteries that allow for the maintenance of a constant frequency and voltage.

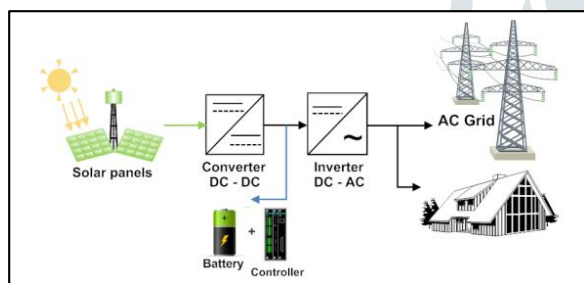


Figure 4: General structure of PV energy.

1.5.1.3 RE Plants Location

The majority of RE plants that provide their energy to the grid are large-scale capacity facilities; hence, space occupied by such a plant is typically quite substantial. There are times when we are prevented from choosing the locations of the RE sources due to a number of variables; however, each technology has its own set of justifications for selecting a site. When deciding where to run one of RE technology's components, there are several factors to consider, all of which can make RE-Grid integration difficult. To begin, some RE sources are not accessible in all areas. Second, the weather, climate, and geographical location all play a role in RE sources (Commission, 2012).

1.5.1.4 Cost issue

Planning for the integration of RE Grids requires careful economic calculation so that integration costs can be kept to a minimum. The inclusion of RE has two primary goals: protecting environment & lowering price of power generated by both RE and conventional plants.

1.5.2 The Benefits

As the impact of RE-Grid integration has been validated, advantageous aspects of RE-Grid integration may primarily be categorised as follows: social, environmental, and economic

advantages. Secondly, RE technologies produce no fossil fuel emissions; therefore, integrating them will assist fossil fuel power generation facilities in lowering their CO₂ emissions by reducing the amount of power they generate (Bird et al., 2013).

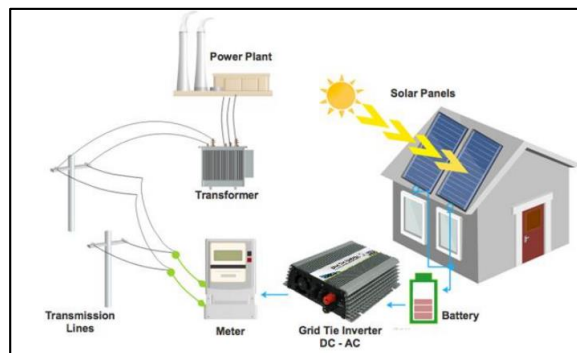


Figure 5: General integrating process using GRI.

Because of the reduction in CO₂, both our culture and the natural world will become less polluted and more robust. Integration also boosts the dependability of power grid breakdowns due to the fact that it makes use of a storage system. To put it another way, a lot of individuals nowadays insulate their own energy sources, like solar energy, so they can sell excess energy to utility & have their own electricity in the event that the grid goes down (Bird et al., 2013). Figure 5 depicts the overall picture of how solar energy can be integrated into the grid in residential settings through the use of grid tie inverters.

1.6 LITERATURE REVIEW

(Ahmed et al., 2022) This study proposes a novel method for monitoring large-scale grid-connected PV modules in solar power plants by combining the traditional image processing methods with the cutting-edge object detection YOLOv5 algorithm. By using a drone to fly over the solar park and record movies, a completely automated system has an essential component that they have highlighted. Videos that have been previously processed are used to train the YOLOv5 model to distinguish between clean and dirty panels. A Raspberry Pi can be used to implement the process which is specified for a particular site. This system analyses the data from the drone photographs, creates a report and automatically emails it to the relevant department each day so that timely maintenance may be carried out to ensure the longevity and security of solar arrays. The inspection period for the same process was lowered from around 120 hours to 5 minutes. It indicates that vision and effective automation approaches save 99.93 percent of the time.

(Sterl, 2021) In order to expand access to electricity in Africa at a reasonable cost while decreasing emissions from fossil fuel use, this study assesses recent scientific findings regarding the integration of "variable renewable electricity" (VRE) sources, primarily solar PV & wind power, on power grids across the continent. In this context, improved cross-border transmission infrastructure between African nations has received major research focus, as well as storage options like power-to-gas & battery storage, in order to utilise spatiotemporal complementarities between renewable electricity supplies.

(Boretti, 2021) Being a "New Future" metropolis, NEOM relies solely on RE sources such as solar PV, solar thermal, & wind to provide enough electricity to meet the city's total demand, all of which is monitored and managed by artificial intelligence. It is expected that solar thermal's prominence will grow in this setting.

Only concentrated solar electricity, among renewable sources, has the additional benefit of being dispatchable. Concentrated solar power, in contrast to solar photovoltaic and wind, can be outfitted with internal energy storage using molten salt, giving a considerably cheaper and ecologically beneficial option due to the former's intermittency and the latter's unpredictability. In NEOM City, Saudi Arabia, highly dispatchable electricity with a "Levelized Cost of Electricity" (LCOE) slightly above 7.5 cents per kilowatt-hour is possible thanks to an oversized solar field & thermal energy storage system using steam Rankine cycles with temperatures & pressures to the turbine of about 565 degrees Celsius and 100 bars. In order to reduce the LCOE even more, increasing the turbine's operating temperature and pressure to 730 °C and 330 bar, respectively, is required. Although wind & solar PV are relatively inexpensive at less than 3–4 cents per kilowatt-hour (¢/kWh), they are also highly variable and unpredictable, which means that energy must be stored using Lithium-Ion batteries at an additional cost of 14–28 ¢/kWh. Solar PV, battery energy storage, wind, & solar thermal will form the foundation of NEOM City's renewable energy infrastructure, with solar thermal accounting for an ever-increasing percentage of the city's total energy production in the near future thanks to the integration of AI.

(Sterl et al., 2020) The potential for expanding the proportion of RE sources in Suriname's electrical mix is examined in this work, with a particular emphasis on the complementing roles of current hydropower & future wind power facilities. They show how effectively these resources can work together to replace fossil fuel-based electricity generation. Large wind power integration is made possible by the flexible operation of the recently fully-owned Afobaka hydroelectric facility without jeopardising grid stability or related power quality standards. Incorporating wind power into Suriname's electricity mix is economically beneficial, up to a share of 20 to 30 percent, independent of near-term demand growth, according to their findings, which take into account the trade-off between replacing expensive fossil fuels & limiting wind power on the island-like grid.

(Wu et al., 2019) In this study, grid codes from around the world pertaining to the integration of wind power are compared. A number of countries' grid codes, including those of Ireland, Denmark, the United Kingdom, Germany, China, Spain, the United States of America, and Canada, are taken into consideration. Reactive power, frequency management, & power quality are aspects of these grid codes that are considered to be the most significant. Communication and offshore wind power plants are also topics that are covered by several grid regulations. In order to help system operators ensure a secure power system operation that involves a sizable portion of wind power output, this study includes information on future grid code requirements for the integration of offshore wind power.

(Talaat et al., 2019) This paper presents a hybrid PV/Wind/Wave energy system dynamic modelling and control. To improve the efficiency of the RE system, wave energy, PV, and "wind energy conversion systems" (WECS) have been incorporated into the primary DC bus bar. A DC-DC converter has been installed in the wave energy and PV systems, and an AC-DC converter has been installed in the WECS. To obtain a consistent DC bus-bar voltage, the entire hybrid system is then linked to a microcontroller system and buck-boost converter. The necessary load or batteries are linked to the hybrid system's output voltage at this point. With the purpose of studying how to combine and synchronise the generation of energy from these 3 separate RE sources, an

experimental test bed has been built. A definite obstacle to the output of wave energy changing due to variations in the wave's strength, direction, and height has been included in the study of wave energy. How convert this energy into electrical energy has proven to be a difficult task. Studies on wind and solar energy also take into account various environmental factors, such as variations in solar irradiation and wind speed. Hence, combining wave energy with solar and wind energy provides a significant difficulty. The MATLAB/Simulink environment is used to implement analysis & simulation modelling of the HES. In the design of the integrated circuit, the Buck-boost circuit concept is given and examined. The simulated model's effectiveness is determined to be realistic, and it is demonstrated that the model is utilised in the integration of 3 proposed energies.

1.7 Conclusion

This study leads us to the conclusion that electricity systems will need to be flexible in the future. High percentages of wind and solar energy will necessitate the development of more adaptable power system components from manufacturers. Operators of the power grid will need to adapt their infrastructure to the anticipated renewable installations. The system will benefit from incentives for highly flexible power plants, & demand-side response. The findings also allow us to offer additional justifications for pursuing global solutions as the most effective means of integrating renewable energy sources on a big scale.

The effects of greenhouse gas emissions and global warming have resulted in a rapid proliferation of renewable energy technologies over the past few years. This growth has contributed to a rise in the number of RE sources that are integrated into the system grid. The incorporation has been having some trouble achieving links in the appropriate form, which has caused considerable frustration. The most significant obstacles, including generation forecasting, the availability, fluctuation, and speed of power; power quality issues; and the location of renewable energy facilities, have been explored in this study.

Speaking of RE's advantages, the RE-Grid integration's advantages were evident. Benefits of RE-Grid integration include improved environmental and human health, more employment opportunities, and assistance to societies in the event of power outages.

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